# CENTRAL INTELLIGENCE AGENCY

# INFORMATION REPORT



SECRET
SECURITY INFORMATION

50X1-HUM

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| SUBJECT | Turbojet and Turboprop Development Project at Zavod No. 2, Kuybyshev | DATE DISTR. | 15 May 1953 |
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THE SOURCE EVALUATIONS IN THIS REPORT ARE DEFINITIVE.
THE APPRAISAL OF CONTENT IS TENTATIVE.
(FOR KEY SEE REVERSE)

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[redacted]

AIRCRAFT TURBOJET ENGINES UNDER CONSTRUCTION AT ZAVOD NO. 2, KUYBYSHEV

1. Development work on the following turbojet engines took place:

   a. BMW-003

   [redacted] this turbojet engine [redacted] 50X1-HUM had been improved and development completed in August 1947. It was reportedly in production at an unknown factory in Kazan.

   b. BMW-018

   [redacted] work on its development stopped in the autumn of 1948. Some testing had been done at Zavod No. 2 in 1948.

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   c. JUMO-004

   [redacted] production was reported to be taking place in Ufa.

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| STATE | #x | ARMY | #x | NAVY | #x | AIR | #x | FBI | | AEC | | | | | |
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[redacted]

d. JUMO-012

[redacted] this engine [redacted] had been shipped after completion in the autumn of 1948 to Kazan./

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e. Soviet Nene

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During the period [redacted] one problem was to improve the specific fuel consumption. [redacted] they wanted the SFC of the 012 down to 1.05 kg/hr/kg thrust. The group was furnished with performance reports on the Nene engine for their project in reducing the SFC. These tests had been run at Tsiam either at the end of 1947 or the beginning of 1948 [redacted] The SFC of the Nene indicated in the report was 1.1 kg/hr/kg thrust. [redacted] Two were used on the 012 and 022 and were tried because of the serious ignition difficulties encountered. They were used successfully [redacted]

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## AIRCRAFT TURBOPROP ENGINES UNDER DEVELOPMENT AT ZAVOD NO. 2

2. Testing of the following turboprop engines was conducted at Zavod No. 2:

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a. JUMO-022

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[redacted] The 022 engine was ready for test before the propeller, reduction gear, and governor accessories had been completed. Therefore, during the first six months of 1949, only motoring tests (exact date unknown) and preliminary performance tests on the engine were run. The latter part of 1949 the engine and accessories were tested. The propeller unit was then installed and a fixed pitch propeller (ground adjustable) was used until March 1950. After March 1950 a controllable pitch propeller system was used. Details on the performance and characteristics (especially weights and dimensions) are difficult [redacted] to recall with accuracy. The most accurate [redacted] is believed to be the engine test and fabrication details. /However, the engine characteristics listed below are believed to be reliable [redacted]

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(1) Engine Characteristics

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| | |
|---|---|
| Maximum Diameter | - 1300 mm. |
| Compressor | - 14 stage axial flow |
| Turbine | - 3 stage |
| Combustion Chamber | - 12 cans (cannular arrangement) |
| Exhaust Cone | - Fixed |
| Pressure Ratio | - 4.2:1 |
| Fuel | - Kerosene |

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[redacted]

(2) Engine Performance

| | |
|---|---|
| Take-Off - | 4200 HP plus 300(?) kg.thrust at 7500 rpm plus or minus 50 rpm (5-minute rating) |
| Maximum - | 7250 rpm plus or minus 50 rpm |
| Cruise - | 7100 rpm plus or minus 50 rpm |
| Idle - | 3500 rpm plus or minus 50 rpm |

Turbine Temperature (first stage inlet)- 840° C
Turbine Temperature (third stage outlet)- 480° C 
Air Flow - 58 kg/sec

[redacted] the "specific fuel consumption of the 022 was now 270 gm/hr/h.p. at T.O. power". There were two pressure relief valves on the 5th stage of the compressor. The valves (100-110-mm diameter) were opened by an oil pressure governor when the compressor reached 1000 rpm. The relief valves automatically closed at 5400-5600 rpm.

(3) Propeller Information

Two contra-rotating, reverse pitch, full feathering, and fully controllable types were produced at a factory in Moscow (Zavod No.20). A German engineer, LEUTHOLD, was in charge of a great deal of the design work on the propeller and controls. 

Diameter - 4200 mm. [redacted]
Blade Width - 300 mm.
Number of blades per propeller - 4
Reduction gear ratio - 6.95:1 (Ing. GASSENMEYER and ELZE did a great deal of the design work on the reduction gear)



(4) Engine Test Procedures

[redacted]

(a) Idle Test

Using the air turbine starter (about 60 HP at 36,000 - 38,000 rpm) developed at Zavod No.2, it took 80-90 seconds to bring the engine up to the idle point of 3500 rpm. All the instruments were checked; noises, vibrations and any leaks were noted. The fuel was then turned off and the following data recorded:

1. Elapsed time from 3500 rpm to zero rpm (average time was approximately 180-210 sec under normal conditions)

2 Elapsed time from 1000rpm to zero rpm (average time was approximately 70-110 sec.)

The following data were recorded at idle rpm:

1 Propeller rpm

2 Fuel pressure

3 Oil pressure

4 Turbine exhaust temperature

5 Pressure and temperature at compressor inlet

(b) Propeller Governor Test

The engine was started and run at 4500 rpm. At 4200 rpm the propeller governor was actuated. The oil pressure at the governor, in the low pitch position, during starting was 25 atm.; at 4200 rpm the oil pressure was down to 3 atm. Then the high pitch regulator pressure went down to 12-13 atm. and stayed there. This test was run to check the functioning of the propeller governor. In addition, the following data were taken at 4500 rpm operating speed:

1 Propeller rpm

2 Fuel pressure

3 Oil pressure

4 Turbine exhaust temperature

5 Pressure and temperature at compressor inlet

The engine was then shut off and the following readings taken:

1 Elapsed time from 4500 rpm to zero

2 Elapsed time from 1000 rpm to zero

(c) Engine Performance Tests

Measurements of horsepower, thrust, rpm, fuel pressure, oil pressure, turbine intake and exhaust temperatures, compressor inlet and outlet pressure and temperatures were measured at the following speed:

1 7500 rpm (measurements taken during 5 min. test)

2 7250 rpm (measurements taken during 30 min. test)

3 7100 rpm (no limit on time)

At Zavod No. 2, during the spring of 1950, a 100-hour test was attempted but a reduction gear failure at 32 hours of testing prevented its completion. Some tests were also run in 1950 on

the 022 with tailpipe attached. Three different sizes were used, a 2-1/2 meter, 3 meter, and 3-1/2 meter long tailpipe (measured from the third turbine casing flange). Results of tests were unknown.

(d) Flight Tests



[redacted] the flight tests were passed during April-May 1951.

(5) Disassembly and Inspection Procedures After Engine Performance Tests



[redacted] disassembly procedures on the 022 turboprop [redacted] the engine was run through various tests [redacted] The disassembly and inspection procedures (described below) were conducted by qualified personnel. (These steps were followed after every performance test.) [redacted] The various component assemblies (such as compressor, combustion, turbine, propeller assembly, etc.) were sorted and placed on separate tables for inspection. This procedure insured that the inspecting engineers would see only the parts that they were responsible for. [redacted] After the engine was stopped and the test run completed, the following procedure was carried out while the engine was still on the stand:



(a) All the propeller blades were removed.

(b) Propeller hubs, with oil lines and accessories attached, were removed next.

(c) Propeller shaft pulled off.

(d) Bell-mouthed intake manifold removed.

(6) The engine was then removed from the test stand (after all connections were broken) and placed nose down in a tubular jig arrangement. The base of the engine was approximately one foot from the floor level. The engine was held suspended in the jig by chain hoists. The following disassembly procedure was then followed:

(a) The exhaust cone flange was unbolted (aft of third turbine wheel).

(b) The third turbine rotor wheel was removed (before taking the wheel off, the blade clearances were measured by using a feeler gauge). The wheel was lifted off by a chain hoist.

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 [redacted]

(c) Third stator stage was removed.

(d) The second turbine rotor, stator and then the first turbine wheel and stator were removed as described in steps b and c (blade clearance was also measured prior to removal).

(e) Turbine housing flange was broken and housing removed.

(f) Combustion chamber assembly flange was broken and combustion chamber section removed.

(g) Turbine shaft was pulled out.

(h) Flange at the last compressor stage unbolted and the combustion fuel manifold section removed (a coupling shaft came off with it).

(i) The two halves of the compressor casing were split, separated, (with stator vanes) and removed.

(j) The compressor rotor assembly was lifted out by a hoist.

(k) The remaining reduction gear assembly was lifted out of the jig.

(7) All of the disassembled components were then laid out on tables (component sections were kept together) and the following inspection procedures performed:

(a) A visual inspection of the parts while still in the dirty stage was conducted by the interested inspecting engineers.

(b) Parts were then cleaned, measured, and inspected again.

(c) A report was written by the inspecting engineers.

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(8) [redacted] the following components appeared to suffer the most damage during the performance test runs:

(a) Turbine stator rings had heat and vibration cracks.

(b) Compressor stator blades failed due to vibration cracks.

(c) Combustion chamber liners had holes and cracks in them, especially at the heads. The most frequent trouble was experienced with the combustion system.

(d) Turbine bearings seized and burned (an oil mist spray was tried using 12 nozzles in a ring around the bearings. It still hadn't functioned too well

[redacted] 50X1-HUM

(e) Front compressor bearing clearance was out of tolerance frequently.

(f) Reduction gear malfunctions were also number one on the list (the 100 hr qualification test was terminated because of a reduction gear box failure).



**FABRICATION AND INSPECTION METHODS USED ON COMPONENTS OF THE 022 TURBOPROP**

3. [redacted] These were not the production methods to be used on the 022 but were merely the fabrication procedures being used for the experimental engines up until October 1950. [redacted] In most instances the methods used were not influenced by the Soviets in any way. The machines were all of foreign make, mostly German.



a. Machined Compressor Wheel

The compressor rotor wheels were machined from rough forgings. [redacted]



b. Machined Compressor Rotor Blades

The following step-by-step procedure was used to fabricate the compressor rotor blades for the 022 [see sketch, page 18]:

(1) The block of blade material was placed in the jig and clamped in position under the cutter. The blade blank was clamped in at an angle so the blade contour could be correctly milled by the cutter. [redacted] Dimensions of the blade during any part of the fabrication process were unknown.



(2) The outside contour of the blade was then milled by the cylindrical cutter. The cutting cylinder width spanned the complete blade length (rotational speed not known). It was made of case-hardened steel. The profile was cut as follows: the blade blank had two movements during the cutting operation; it moved forward under the stationary cutter and at the same time pivoted around its longitudinal axis in order to form the contour (profile movement). A follower fastened to the clamping jig of the blade copied the blade profile which was cut into a profile block [redacted] Since the blade blank was fastened to this clamping jig, this action kept the blade correctly positioned while it was moving under the cutter in order to form the correct profile.

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(3) After the outside contour was cut, the blade blank and profile block were turned over and the inside contour formed in a manner similar to that described in step (2) above.

(4) The partially completed blade was then taken out of the milling machine. The leading edge and trailing edge contours were not cut during steps (2) and (3) (see step (7) ). The blade was taken and placed tip end down in a jig installed on the table of a universal horizontal milling machine [see sketch, page 21]. The root end was cut by the two fixed cutters. The traverse table, on which the blade jig was attached, moved under the two fixed cutters carrying the root end of the blade between the rotating cutters and thus formed the root profile. The height of the table could be adjusted to compensate for the different blade lengths of the various compressor stages [see sketch, page 21 ]. [redacted] 50X1-HUM

[redacted] the important details of the process used to form the root profile are shown. [redacted]

(5) After this step, the blade was placed in a die (inner side down), fastened, and moved under a cutting wheel which milled out a groove along the length of the blade root (an identical groove was cut into the compressor wheel rim and a pin driven in to attach the blade to the wheel) [see sketch, page 22]. 50X1-HUM

(6) The blade was removed from the jig and the excess tip stock was removed by grinding.

(7) The leading edge and trailing edge was filed to shape and smoothed with emery paper. This operation only took three or four minutes and was faster than trying to machine the edges.

(8) The outside and inside radii were rounded off (junction of root to blade). [redacted] 50X1-HUM

c. Checking and Inspection of Compressor Rotor Blades

The finished blades were not polished since it was found that no improvement in performance resulted from the polished blades. The control and inspection procedures used in the fabrication of the finished compressor rotor blades were as follows:

(1) A profile template was used to check the tip profile for accuracy.

(2) The over-all length of the blade was measured.

(3) Each blade was weighed.

[redacted] 50X1-HUM

[redacted]

d. Compressor Section Balancing Procedure

The following procedure was performed when balancing the compressor assembly:

(1) The compressor shaft was balanced while it was rotating at high speed.

(2) Rotor wheels (minus blades) were checked and out of balance points noted. No corrections were made in this step.

(3) Rotor wheels plus blades were individually checked and balanced.

(4) All 14 compressor rotor stages were installed on the shaft and the whole assembly was statically balanced and run.

e. Fabrication of Compressor Stator Blades

The stator blades were rolled out of 1-mm sheet stock (45 kg/mm tensile strength) and welded to the compressor case. This type of blade was unsatisfactory due to excessive vibration cracks. [redacted] 50X1-HUM

f. Machined Turbine Rotor

The turbine rotor was machined from a forged blank. [redacted]

g. Forged Turbine Rotor Blades

[redacted] Until September 1950, the following steps were involved in fabricating the turbine rotor blade [see page 23].

(1) The rough blade blanks [round stock as shown by Step 1, sketch on page 23] as received in the forge shop were placed into an oven by a worker and heated to approximately 600°-700° C. [redacted]

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[redacted]

(2) A second worker, who was at a forging hammer, received the heated blade stock and placed it on the die, whereupon the first forging operation was performed. The compressed air hammers operated at eight atmospheres pressure. The method of forming these blades was a bit unusual. The worker at the air hammer picked the rough blade stock /see Step 1, sketch on page 23/ by the root end with a pair of tongs. The stock was placed on the die, jiggled a bit to make it fit; then the tongs were withdrawn and the hammer released to form the first forging operation.

(3) A specific number of blades were put through this initial forging operation, then the die was changed and the second step was completed. For example, if the order called for 100 blades, 100 pieces of blade stock would be heated and run through the first forging operation (after each forging operation the blade would be returned to the oven for heating) and then a second die would be placed under the hammer. The heated blades would be taken out of the oven and put through the second forging operation. The heated blade /see Step 2, sketch on p.23/ was gripped by the root end with tongs and inserted into a second die. The tongs were withdrawn and the hammer dropped to form the blade root (in a rectangular shape) and also refine the blade profile. In all forging operations the root end of the blade was pointed toward the operator.

(4) These blades were then put into the oven, heated to temperature, withdrawn from the oven, and inserted into a die /see Steps 2 and 3, sketch on page 23/. This was the final forging operation and it refined the blade profile and root appearance.

(5) These blades were then taken to a short peening department. At first the blades were sand blasted after Step 4 /see sketch, page 23 /but in 1950 this gave way to shot peening. Each individual blade was held with a pair of tongs in an inclosed box that had an air gun mounted in the side. The compressed air gun (5 atm. operating pressure) was filled with shot /see sketch, page 23/. The operator, holding the blade with tongs in one hand, operated the air gun with his other hand. All blades were shot peened. [redacted]



(6) These blades, after shot peening, were then returned to the shop and the excess tip stock was cut off and the fir tree root formed by a vertical milling machine [redacted]

(7) The complete blade was then ground by an emery wheel (a five-times-size pattern was followed for all steps). The grinding procedure perfected by Dr.BREDENDIK was performed as follows:

(a) The outside profile of the blade was ground to finish (in Steps "a" thru "d", the blade was attached to a traverse table which moved under a stationary grinding wheel).

(b) The inside profile was ground to shape.

(c) The outside radius at the juncture of the blade and root was ground.

(d) The inside radius of the juncture was then ground to shape.

(e) The blade was removed and inserted into a jig in the vertical position (root end down) and a grinding wheel was moved vertically up and down the leading edge radius of the blade, grinding it to shape.

(f) The trailing edge was ground in the same manner as the leading edge. The blade was not hand-polished.

(8) The finished blade was then weighed and checked for tolerance. Template gauges were used to check the profile. The inside and outside profile of the blade were checked at three stations, necessitating five separate gauges (two for the inside profile, two for the outside profile, and one gauge which checked the inside and outside profile simultaneously at the tip section) /see sketch, page 24/. The tip profile station was checked by inserting the blade tip into a gauge block which had the profile cut into it to the correct depth. The grinding procedure was so accurate that rejects were very few (percentage unknown).

(9) The fir tree root was checked (for correct fitting) by sliding it in and out of a milled root pattern in a rotor wheel.

(10) A number was electro-etched on the bottom side of the root section. 50X1-HUM

[redacted]

h. Turbine Rotor Balancing Procedure

Turbine rotor balance was effected by interchanging blades of different weights where needed.

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[redacted]

i. Combustion Chamber Assembly

The combustion chamber flame tubes were fabricated of rolled sheet metal (seam welded once).

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j. Component Manfacturing Methods

[redacted]

BMW 028

The BMW group did only design work on the 028 until the fall of 1948 (when the Junkers and BMW groups merged). No test work was done at Zavod No. 2 on the BMW 028. The drawings were all packed up and shipped to Tsiam and Kazan in the fall of 1948.

**FUELS**

4. The fuel used for the engine testing at Zavod No.2 was delivered by truck to the factory. The fuel was then transported to the laboratory and tests run to see if it met the specifications. When the fuel was delivered to the laboratory, there were shipping tags attached to the containers. These tags had the fuel name and specification written on them. Since the fuel was used in the engine testing [redacted] 50X1-HUM This laboratory test was necessary because occasionally there were impurities in the fuel (and at times the specified tolerances were not correct). If the fuel did not meet the specification, it was not accepted.

a. The fuel was designated ГОСТ XXXX - XX [redacted] 50X1-HUM The translation of this number was as follows: 50X1-HUM

(1) ГОСТ - [redacted] not know what this signified [redacted] 50X1-HUM

(2) XXXX - a catalog number (4 digits) given to the fuel by a Ministry in Moscow.

(3) XX - the last two numbers of the specification denoted the year that the specification was passed. 50X1-HUM Since it was known that the Soviets do use the designation ГОСТ XXXX - XX for fuels [redacted]

b. The fuel specifications were sent by the Germans (at Zavod No. 2) to the Ministry of the Aviation Industry. If accepted, it was given a catalog number (ГОСТ XXXX - XX ) so that it could be ordered directly from the stocks.

c. The fuel used in the 022 testing was a kerosene type. The following data were known about the fuel:

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[redacted]

(1) Type - kerosene. No color.

(2) Specific gravity - 0.83

(3) $H_u$ =10400 K Cal/kg ($H_u$ designated the LHV of the fuel - the "u" stood for the German word "unter", meaning lower)

(4) $H_o$ - 10800 K Cal/kg ($H_o$ designated the HHV of the fuel - the "o" stood for the German word "ober", meaning higher).

**LUBRICANTS**

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5. A 70-30 mixture of oil-kerosene was used with success as a lubricant for the 022 (70% oil). Hydraulic oil used was of an old German type /called "Fahrwerk Spindel Oil gruen" [redacted] It was green-colored. Oils also were specified by the [redacted]

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**MATERIALS**

6. Turbine rotor wheels were made from a steel alloy designated XMN (tensile strength 120 kg/mm²). Turbine rotor blades were fabricated from an alloy designated ЭИ-417. [redacted] The chart /see sketch, page 25 / was prepared by the plant that manufactured the turbine blade material. It showed tensile strength (kg/mm²) vs temperature (°C). The tensile strength of the material at 860°C was 8 kg/mm² [redacted] the first stage turbine inlet allowable temperature was 840°C [redacted] this temperature was not exceeded as the material could not survive). This figure of 8 kg/mm² at 860° C was the specification by the plant manufacturing the blade material. However, in their test calculations it was found that the tensile strength of the material at 860° C actually was 10 kg/mm² Combustion cans were made from a material that had a tensile strength of 50 kg/mm². Compressor rotor wheels were constructed of an alloy that had a tensile strength of 90 kg/mm².

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**TEST EQUIPMENT AT ZAVOD NO. 2**

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7. There were five test cells at Zavod No.2 [redacted]

a. Test Stand #1 - used for testing turbojets (BMW-003 and JUMO-004). Maximum test capabilities not known.

b. Test Stand #2 - used for testing the 012 and later modified to test the 022 with propeller. 50X1-HUM

c. Test Stand #3 - was the water brake test stand used for testing the 022. [redacted] #3 since most of my work was in this Stand.

d. Test Stand #4 - used for propeller testing only and also for some engine motoring tests (an electric motor of unknown capacity was used for the motoring tests of the 022.)

[redacted]

e. Test Stand #5 - A temporary turboprop engine test stand which was under construction when I left in October 1950. Test limitations unknown.

8. [redacted] 50X1-HUM

[redacted] some of the details of the test setup are lacking. The information that is reported can be considered reliable. [redacted] the test setup for test stand #3 was installed on three different platforms; that is, the engine on one stand, the water brake on another, and the pendulum motor on a third, and not all on one continuous platform [redacted] 50X1-HUM

[redacted] The 022 was attached at three points (one turbine casing point and two points on the front compressor case) to a floating platform constructed of channel steel /see sketch, p. 26/. This platform travels within the rigid test platform. The fore and aft movement of the engine (thrust) is picked up at the rear attachment point by a linkage and oil cylinder arrangement, which transmits the force to a scale which had a dial reading of 0-6 atmospheres (kg/cm$^2$). 50X1-HUM

9. In order to register the torque measurement, an oil cylinder pick-up transmitted the movements to a scale which had a dial reading range of 0-20 atm (kg/cm$^2$). The torque was picked up off the water brake casing. [redacted] 50X1-HUM

[redacted] When the 022 was run on the early motoring tests, without water brake attached, the horsepower had been measured by a linkage and oil cylinder arrangement which measured the torque of the engine. The brake arm was 716.2 mm from the engine center line. The scale of the weighing device had a range of 0-20 atm (kg/cm$^2$). Later, when the cell was modified for use with the water brake, the torque was measured using the water brake absorption technique.

10. The water brake capacity was 9,000 BHP. It operated at 6500 rpm when the water outlet temperature was 60 C. When testing the 022 with the water brake arrangement the standard reduction gear box of the 022 was not used. A special reduction gear box was employed to reduce the 7500 rpm of the turboprop compressor down to 6500 rpm for water brake operation. Although the water brake had a capacity of absorbing 9000 BHP, only 6000 BHP could be measured with the existing arrangement. This was because of the fact that the water brake [redacted] had two rotor wheels, each capable of absorbing 3000 BHP, and provisions for a third rotor wheel which could be installed in the rotor casing when needed, which would also be capable of absorbing 3000 BHP. 50X1-HUM 50X1-HUM

11. Test procedure required the calibration of the thrust and torque indicators before and after each test. This was accomplished by using dead weights to actuate the oil pressure cylinder to record a scale reading. Next a calibration curve of kg (weight) vs. kg/cm$^2$ (dial reading) was constructed. This chart was used to correct the indicated readings taken during the test. In the previous discussion it was mentioned

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that two small indicators, dial reading in $kg/cm^2$, were used for thrust and torque measurement. To convert the readings into horsepower, a curve of $kg/cm^2$ vs kg was used (this used the same scale as the calibration curve). /See sketch, page 27./ Entering the curve with the dial reading of $kg/cm^2$ a figure P (kg) was arrived at. Then, using the formula,

$$N = \eta \left(\frac{Pn}{1000}\right)$$

where N = BHP (Pse)

$\eta$ = efficiency factor for water brake, friction, etc. [redacted] a factor of 0.69 was used./ 50X1-HUM

P = Scale reading converted to kg from chart /see sketch, page 27/.

n = Shaft rpm,

the brake horsepower of the turboprop was calculated. The two converted readings (thrust and torque) were added together to obtain the resultant total BHP of the turboprop.

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## WATER BRAKE ABSORPTION DYNAMOMETER (30,000 HP) PROJECT

[redacted] A 30,000-horsepower water brake was built in 1948 at Zavod No. 2 for a factory in Leningrad [redacted] it was designed and built at Zavod No.2, even though there is no record of such heavy equipment having been built/. [redacted] there had been an order for two more of the same size. The rotor case contained five rotor wheels (each absorbed 6000 horsepower) for the absorption of power. /The operating rpm or any physical characteristics of the equipment were unknown [redacted]

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## AIRCRAFT ENGINE FACTORIES IN THE USSR

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**13. UFA** (N 54-43, E 55-58)

[redacted] working for over a year on a reciprocating engine project at a factory in Ufa. The engine was an 18-cylinder, double-row radial of 2800 horsepower. [redacted] the design had been completed. [redacted] it was taken from a BMW design. [redacted]



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[redacted] JUMO-004 was in series production at Ufa at the end of 1947. The 004 was designated the RD-25 by the Soviets. [redacted] RD was the Soviet designation for jet engine (which is correct), and insisted that the numbers after the letters meant the mass air flow of the engine. For the RD-25 this would mean 24 kg/sec. For this engine it happens to be very close to correct; however, [redacted]





14. KAZAN (N 55-45, E 49-08)

[redacted] a factory in Kazan, Zavod No. 16, was producing the BMW-003 at the end of 1947. The 003 was designated the RD-20. The 012 plans were also reported as having been shipped to Kazan in the autumn of 1948.



15. KUYBYSHEV/BEZYMYANKA (N 53-12, E 50-09)

Zavod No. 24 was reported as producing jet engines in 1948.

16. OMSK (N 55-00, E 73-24)

A factory in Omsk was producing the oil pump for the 022.

17. MOSCOW

Zavod No. 20 furnished the propellers and controls for the 022.



[redacted] aircraft diesel engine project at Zavod No. 500 in Moscow. [redacted]

18. NOVSIBIRSK (N 55-02, E 82-53)

Activity of the engine factory located here is unknown.

19. SVERDLOVSK (N 56-50, E 60-38)

Ignition accessories for jet engines produced here.

20. TOMSK (N 56-30, E 84-58)

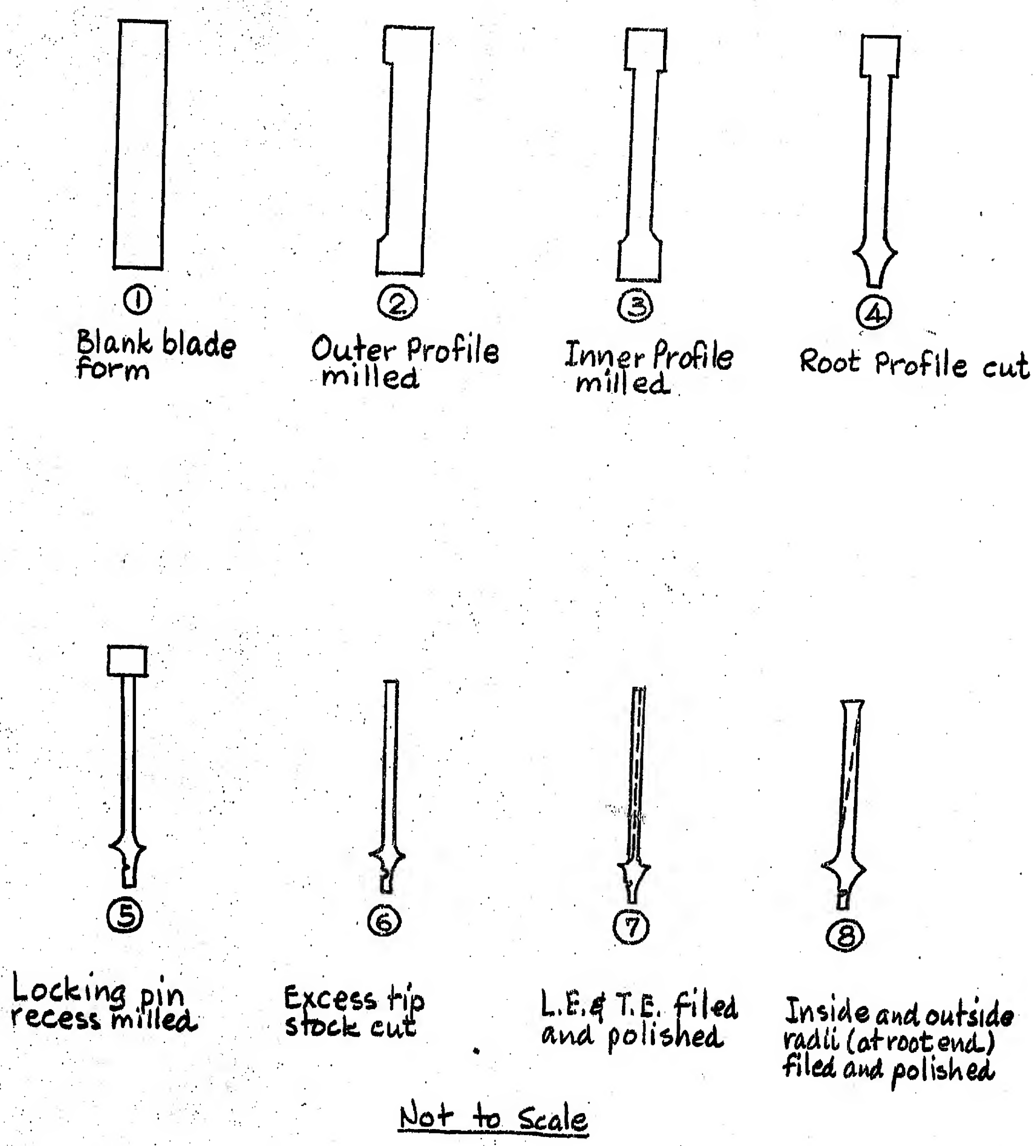
Activity of the engine factory located here is unknown.

21. LENINGRAD

Activity of the engine factory in Leningrad is unknown.

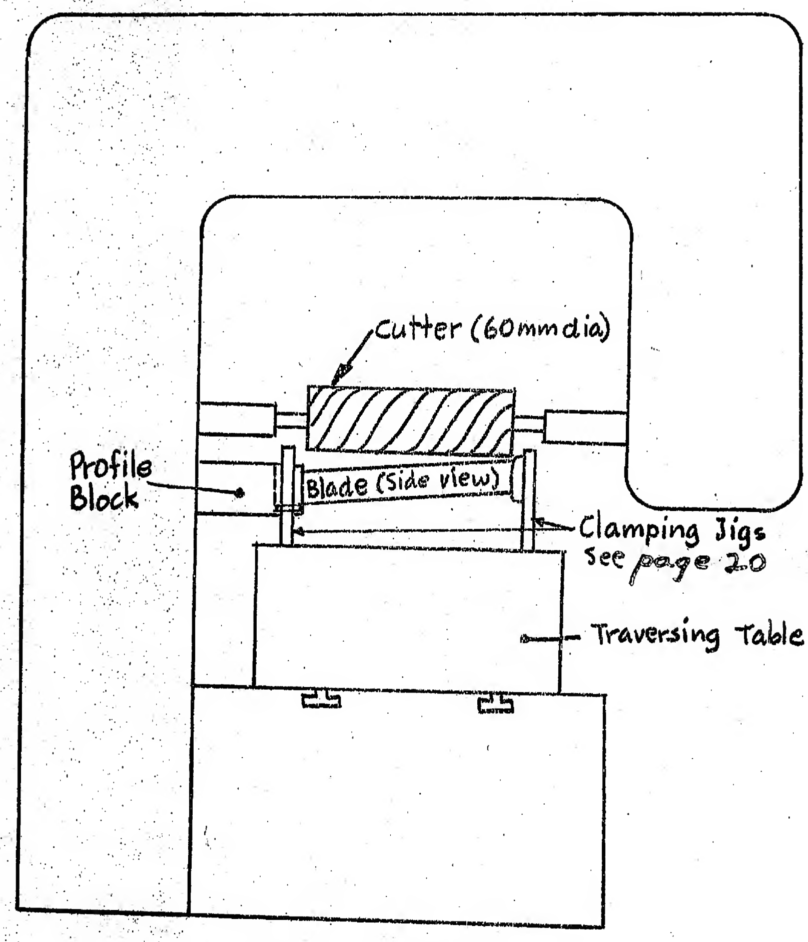
Sketch, page 18: Steps in the fabrication of compressor rotor blade
Sketch, page 19: Compressor rotor blade profile cutting machine
Sketch, page 20: Clamping jig for compressor rotor blade blank
Sketch, page 21: Compressor rotor blade root cutting machine
Sketch, page 22: Method of milling compressor rotor blade root attachment
Sketch, page 23: Steps in turbine rotor blade fabrication
Sketch, page 24: Gauges used for checking turbine blade tolorances
Sketch, page 25: Turbine rotor blade material specification
Sketch, page 26: Water break test stand #3
Sketch, page 27: Horsepower conversion chart

50X1-HUM




Steps in Fabrication of Compressor Rotor Blades

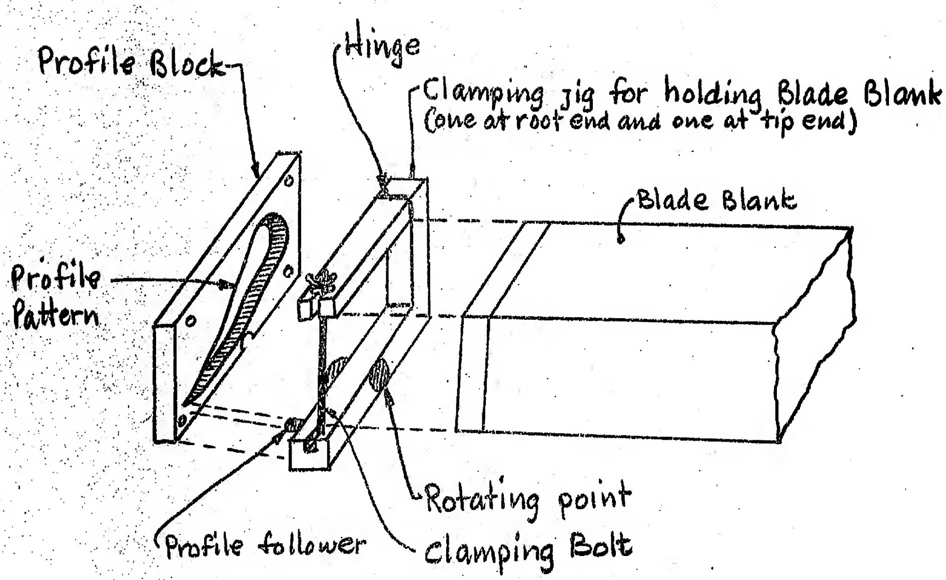
Enclosure: (A




Not to Scale

Compressor Rotor Blade Profile Cutting Machine

50X1-HUM

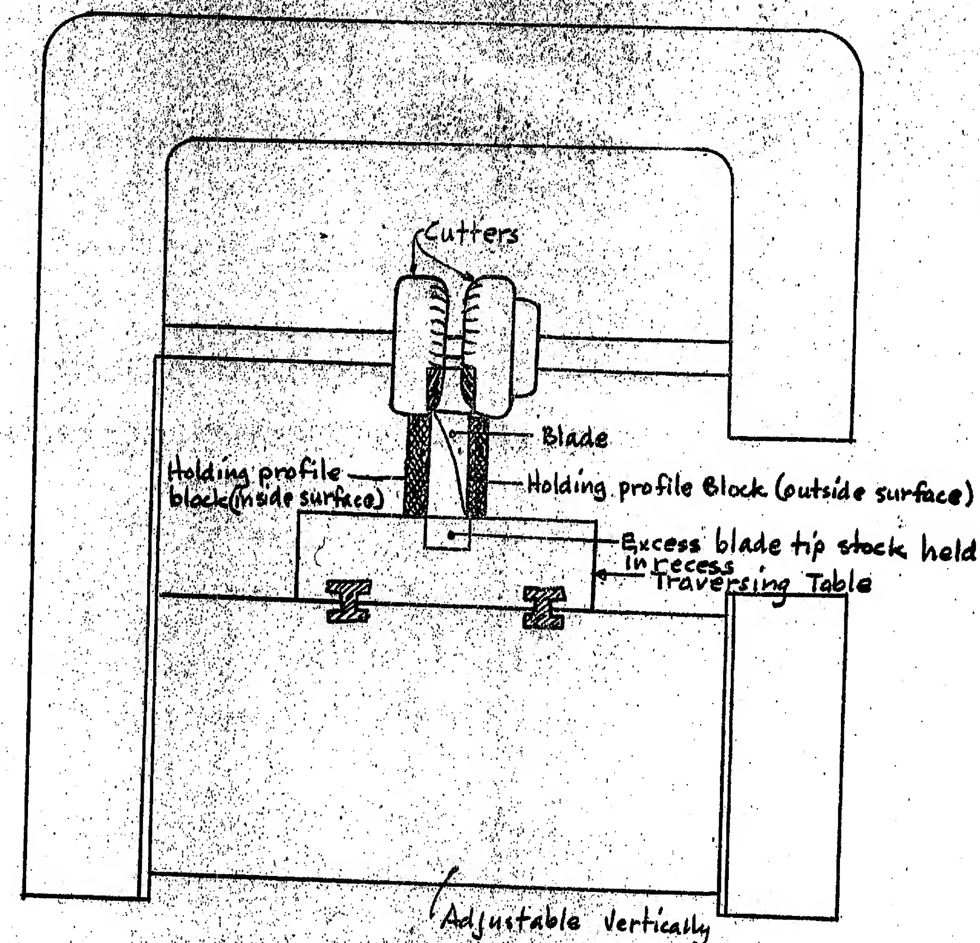



Not to scale

Clamping Jig for Compressor Rotor Blade Blank

Enclosure (c)

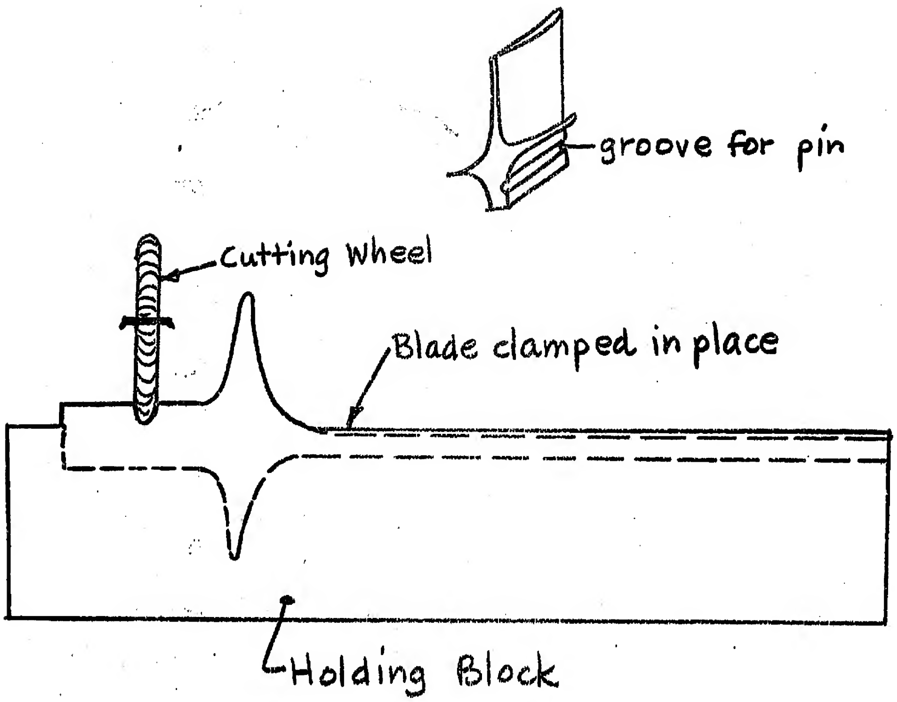
50X1-HUM




No to scale

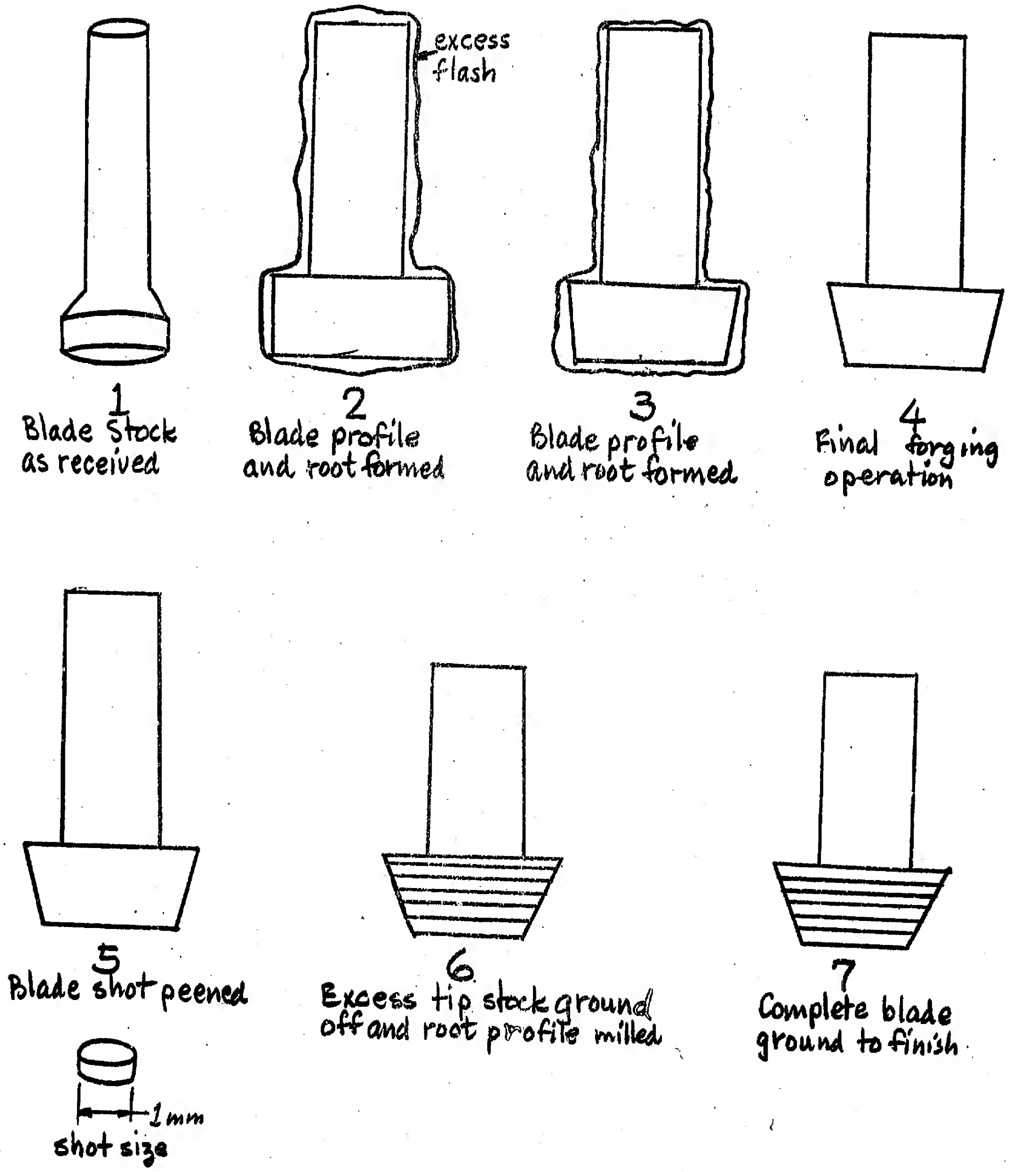
Compressor Rotor Blade Root Cutting Machine

50X1-HUM



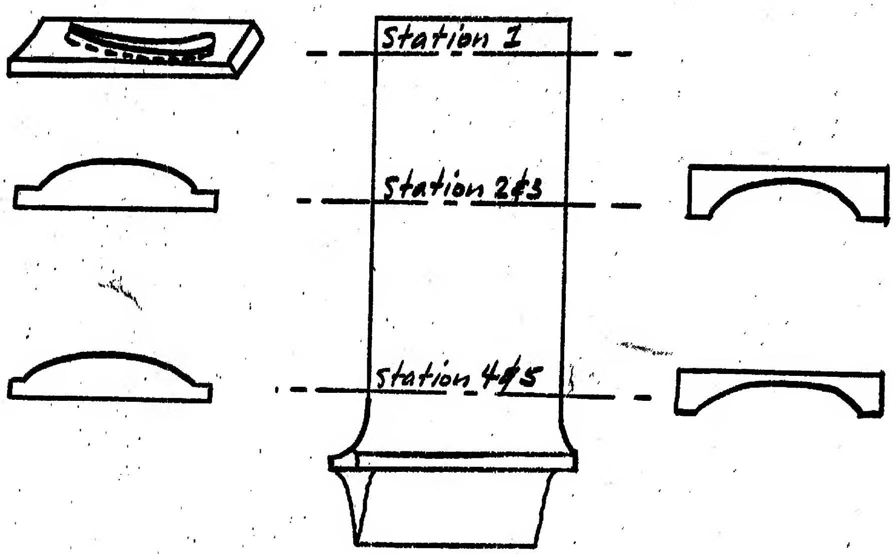

Not to scale

Method of Milling Compressor Rotor Blade Root Groove




Steps in Turbine Rotor Blade Fabrication

50X1-HUM



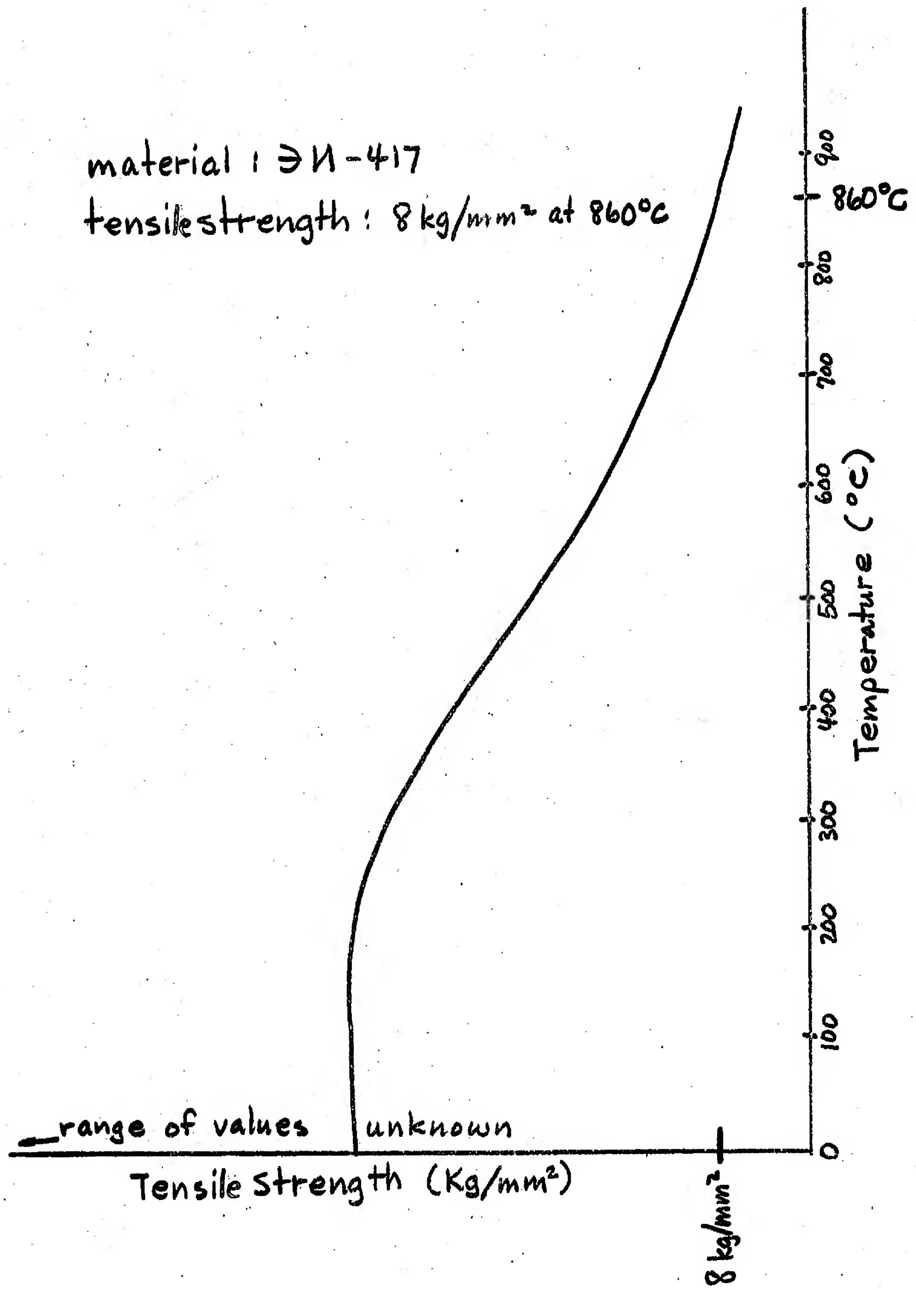

Not to Scale

**Gauges used for Checking Turbine Blade Tolerances**

SECRET



50X1-HUM



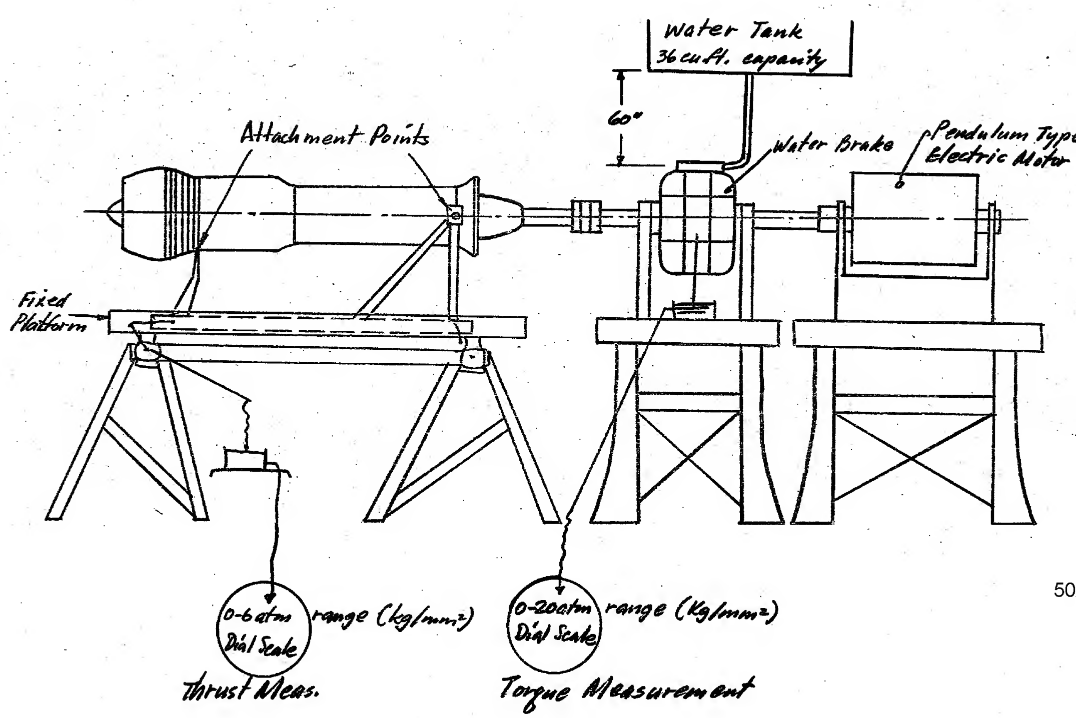

Turbine Rotor Blade Material Specification

SECRET

Water Brake Test Stand

Enclosure (1)

SECRET



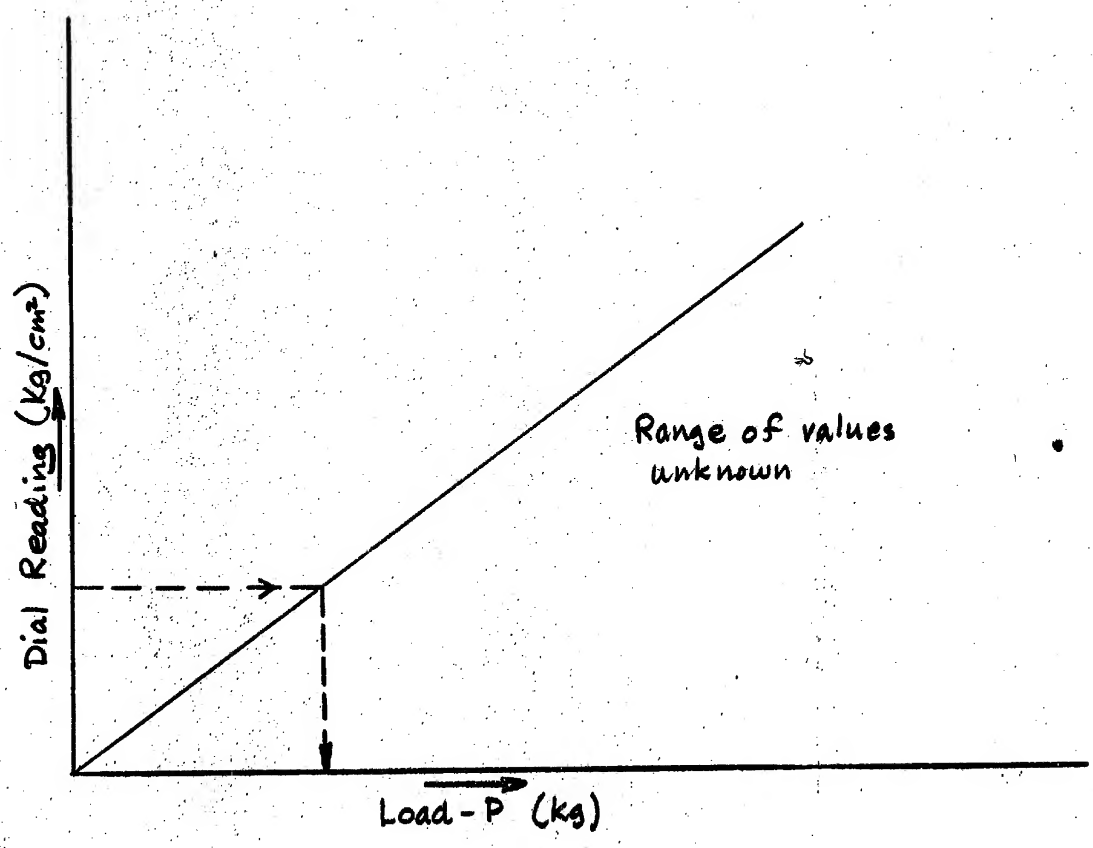

SECRET



50X1-HUM

50X1-HUM

50X1-HUM




Horsepower Conversion Chart

50X1-HUM

Enclosure (J)